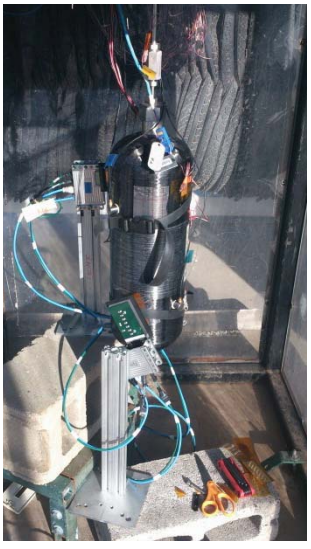
Summary of Activities for Health Monitoring of Composite Overwrapped Pressure Vessels

Updated January 2014

This three year project (FY12-14) will design and demonstrate the ability of new Magnetic Stress Gages for the measurement of stresses on the inner diameter of a Composite Overwrapped Pressure Vessel overwrap. The sensors are being tested at White Sands Testing Facility where the results will be correlated with a known nondestructive technique acoustic emission. The gages will be produced utilizing Meandering Winding Magnetometer and/or Meandering Winding Magnetometer-array eddy current technology. The ultimate goal is to utilize this technology for the health monitoring of Composite Overwrapped Pressure Vessels for all future flight programs.

The first full scale pressurization test was performed at White Sands Testing Facility in June 2012. The goals of this test were to determine adaptations of the magnetic stress gauge instrumentation that would be necessary to allow multiple sensors to monitor the vessel condition simultaneously and to determine how the sensor response changes with sensor selection and orientation. The second full scale pressurization test was performed at White Sands Testing Facility in August 2012. The goals of this test were to monitor the vessel condition with multiple sensors simultaneously, to determine the viability of the multiplexing units (MUX) for the application, and to determine if the sensor responses in different orientations are repeatable. For both sets of test the vessel was pressured up to 6,000 psi to simulate maximum operating pressure. Acoustic events were observed during the first pressurization cycle. This suggested that the extended storage period prior to use of this bottle led to a relaxation of the residual stresses imparted during auto-frettage.

The pressurization tests successfully demonstrated the use of multiplexers with multiple Maundering Winding Magnetometer arrays to monitor a vessel. It was discovered that depending upon the sensor orientation, the frequencies, and the sense element, the Maundering Winding Magnetometer (MWM) arrays can provide a variety of complementary information about the composite overwrapped pressure vessel load conditions. For example, low frequency measurements can be used to monitor the overwrap thickness and changes associated with pressure level. High frequency data is dominated by the properties of the overwrap, including the fiber orientations and layup of the layers.



Year two of this project included tests at White Sands Testing Facility (WSTF) on one vessels which have been intentionally damaged through impact. The first week of testing was performed May 13th, 2013 through May 16th, 2013 on an undamaged bottle. The WSTF system was upgraded at the end of FY 12 and was able to perform a higher level of control, especially during depressurization. The tank was pressurized and depressurized in increments of 1500 psi and held for 10 minutes to produce a stair step pressure profile. The eddy current readings confirmed a settling effect within the first 5-7 minutes of any pressurization hold; therefore, the holds were 10 minutes each to stabilize the readings. 15 complete cycles were performed; 11 using the typical stair step pressure profile and 4 using a continuous ramp and depressurizing ramp down. Two MWM sensors where utilized simultaneously

in two different configurations throughout the tests. Preliminary results show consistent and repeatable data, measurable lift-off/composite thickness measurements, and relatable data to both strain measurements and Acoustic Emissions (AE).

The second week of testing conducted in August 2013, was performed utilizing new MWM sensors specifically developed as a result of this project. These new sensors are an improvement upon the original sensors which include the capability to operate without a Multiplexer Unit (MUX). Testing began on the original, previously scanned vessel to serve as a baseline comparison of the new sensor data to the previously sensors using the same pressurization profiles. After attaining these results, measurements were performed on an intentionally damaged by impact bottle. The impact was calibrated to reduce the strength of the bottle by approximately 20%. Correlation between composite wall thickness and pressurization were successfully measured. Further analysis is planned to refine measurement and analysis procedures in year three. Future work will include coupon testing and a three month long term test.